Original paper

Effect of Incorporation of Silver Nitrate on Transverse Strength and Impact Strength of Autopolymerizing Acrylic Resin

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Abstract

Background: Autopolymerizing acrylic resin has multiple uses in dentistry such as, record base, orthodontics appliances, denture repair and other. The degree of polymerization of cold cured acrylic resin is not as complete as that achieved using heat cured system which leads to a higher degree of un-reacted residual monomer, which act as a plasticizer which results in high transverse deflection values lowering the transverse strength of the resin.
Aim of the study: This study investigated the effect of the addition of different concentrations of silver nitrate (AgNO3) on transverse strength and impact strength of autopolymerzing acrylic resin.
Materials and methods: A total of 80 specimens were prepared, 40 specimens were fabricated with dimensions of (64×10×2.5) mm to conduct the transverse strength test while the remaining 40 specimens were fabricated with dimensions of (80×10×4) mm to perform the impact strength test. 10 specimens of each group were fabricated from conventional autopolymerized acrylic resin while the remaining 30 specimens were fabricated from modified autopolymerized acrylic resin. Concentrations of 9.375,15 and 60 ppm of silver nitrate were used to modify the autopolymerized acrylic resin, 10 specimens of each concentration in each group were used.
Results: The results of this study showed that the modified autopolytmerized acrylic had non-significant difference in transverse strength values for all concentrations of silver nitrate; while there was a significant difference in impact strength values for (15 and 60 ppm) concentrations of silver nitrate and non-significant difference in impact strength values for (9.375 ppm) concentration of silver nitrate .
Conclusions: It can be concluded that the addition of (15 and 60 ppm) concentrations of silver nitrate can improve impact strength of autopolymerizing acrylic resin.
Key words: silver nitrate, modified autopolymerizing acrylic resin, transverse strength, impact strength.

Introduction

Dentistry has used polymethyl-metacrylate acrylic (PMMA) resin since the mid-20th century [(1)]. These materials originate from ethylene and are high molecular weight polymers that polymerize in an addition reaction, with no residual products. Polymethylmethacrylate denture base material usually is supplied as powder-liquid system. The liquid contains non-polymerized methyl methacrylate. The powder contains pre-polymerized polymethylmethacrylate resin in the form of small beads [(2)]. Polymerization

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can be achieved through the application of heat (heat-activated or cured PMMA), chemical, such as tertiary amines (chemically activated PMMA), or by other sources of energy, such as visible light-activated, or through electromagnetic radiation such as in the case of microwave-activated resins.[3] The auto polymerized acrylic resin does not require application of thermal energy to activate the polymerization reaction and therefore may be completed at room temperature that is why it is also called chemically curing acrylic, self-curing acrylic or cold curing resin[2] . The advantage of this material may be in being activated chemically, less thermal changes during time of processing, less internal stresses than heat cured acrylic resin and less time consuming [4], it has multiple uses in dentistry such as denture base, record base, orthodontics appliances, denture repair and other [5]. The degree of polymerization of cold cured acrylic resin is not as complete as that achieved using heat cured system which leads to a higher degree of un-reacted residual monomer[6], which act as a plasticizer which results in high transverse deflection values lowering the transverse strength of the resin. High liquid-powder ratio may also resulted in increasing the residual monomer concentration. [7]. Many attempts have been made to improve the mechanical prosperities of autopolymerizing acrylic, Placing of auto polymerized acrylic resin in hot water during polymerization (60–80°C) Water condition may produce less residual monomer in an auto polymerizing acrylic resin, and transverse strength of the resin was twice when compared with polymerization at 23°C (open to air). This lead to an increase in the mechanical properties and long lasting performance of auto polymerized acrylic resin [8,9]. Microwave post polymerization resulted in a higher degree of conversion and higher flexural strength of an auto polymerizing acrylic resin repair material [10]. Other attempts include the addition of novel glass fiber, polybutene reinforcement to enhance the transverse strength of autopolymerizing acrylic resin [11], addition of poly vinyl pyrrolidone polymer [12]. Silver nitrate is inorganic non- hygroscopic white powder with chemical formula AgNO3. It is a colorless crystalline material that is very soluble in water. It the most important compound of silver, it is used in the preparation of silver salts for photography, in chemical analysis, in silver plating, in inks and hair dyes, and to silver mirrors. It is used in medicine in the treatment of eye infections and gonorrhea. Taken internally silver nitrate is a poison. It is prepared by reaction of nitric acid with silver, and purified by recrystallization. It is darkened by sunlight or contact with organic matter such as the skin [13]. Silver nitrate is incorporated in the poly methyl methacrylate denture resin to attain an effective antimicrobial activity to help control common infections involving teeth and oral mucosal tissues in denture wearers [14]. Therefore, this study evaluated the effect of incorporation of different concentrations of silver nitrate on transvers and impact strength of autopolymerized acrylic resin.

Materials & Methods

A- Specimens grouping:

A total of 80 specimens were prepared to be used in this study. They were divided into two main groups according to the type of the test, each group consists of 40 specimens, each main group were farther subdivided into four sub groups one control and

three experimental according to the concentrations of silver nitrate added where each sub group consist of 10 specimens (Fig. 1).

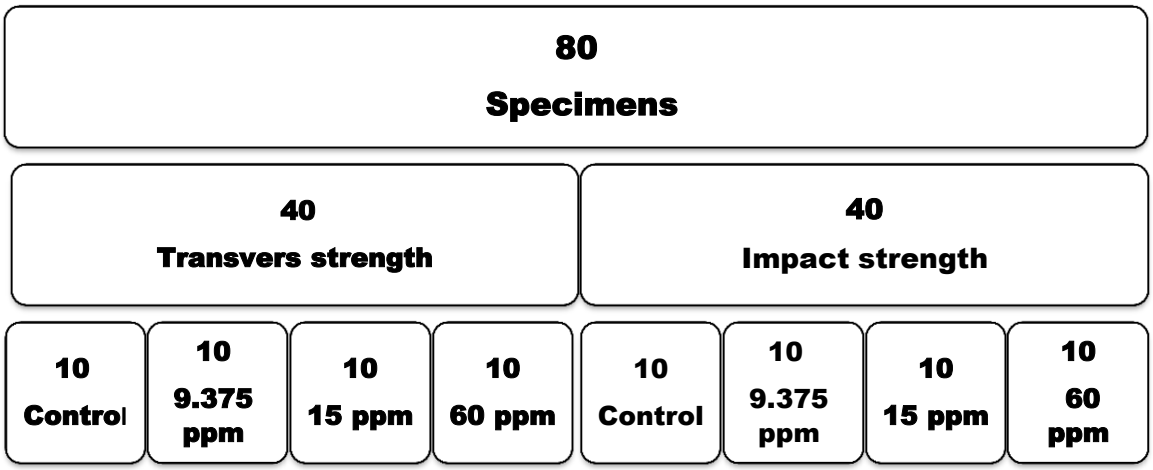

Fig. 1. Specimens groups.

B- Specimens preparation

1- Plastic pattern preparation: hard plastic pattern of different dimensions were constructed according to the required test:

A- Transverse strength test: the plastic patterns were prepared with dimensions of (65±0.3×10±0.03×2.5±0.03mm length, width, thickness respectively) according to ADA No.12, 1999 [15].

B- Impact strength test: the patterns were prepared with dimensions of 80×10×4 mm (length, width, and thickness respectively) according to International Standard Organization 15679 [16].

2- Mold preparation: For the preparation of the stone mold the prepared patterns (for transverse strength and impact strength) were coated with separating medium after that, invested in metal flask which was filled with dental stone type3 (Elite model IVORY, Zhermack, ITALY) that mixed in 30 gm/100 ml (powder/ water) ratio. After final setting of stone material, the plastic patterns were removed carefully (Fig2).

Fig. 2. Mold preparation

3-Specimens fabrication:

A- Control group specimens preparation

Control group specimens were prepared from pink cold cure acrylic resin (Triplex, CE 0123 Ivoclar

Vivadent, Liechtenstein) with 13gm/10ml (powder/liquid) ratio.

B-Experimental group specimens preparation

Silver nitrate solutions of Concentrations 9.375,15 and 60 ppm according to previous study [14], they have closest testing values in comparison with control group were prepared from stock solution of 1000 ppm of AgNO3. The prepared concentrations were confirmed by Atomic Absorption spectrophotometer (phoenix-986/ AA spectrophotometer, UK).

Experiment group specimens were prepared from the same pink cold cure resin with incorporation of silver nitrate solution in a fixed volume 0.2 ml [14] for all concentrations (9.375, 15 & 60 ppm); P/L ratio: 13 gm of powder mixed with 10 ml liquid (8 ml monomer + 2 ml AgNO3 solution of each concentration).

4-Cold cure acrylic manipulation: Sprinkle on technique, in which the polymer is saturated by its monomer, the polymer and the monomers were applied alternately until the mold was filled. left to be set in the room temperature(23+ 2°C) for 20 minutes (open to air), after curing, each specimen was retrieved from its respective mold and the excess was trimmed gently with an acrylic bur (Fig3). The accuracy of the dimensions was verified with a digital vernier caliper, at three locations of each dimension to within 0.2 mm tolerance.

Fig. 3. Cold cure acrylic manipulation

5- Finishing and polishing: All the specimens were finished and polished with a lathe-polishing machine with speed of 400 rpm. To avoid excessive heat, which may lead to distortion of the specimens, pumice (Nekmuice pumice powder fine grained 45μm used in polishing with a large amount of water. Polishing was accomplished using bristle brush and rage well until glossy surface was obtained. All specimens were conditioned in water at 37 ° C for 48 hours before being tested according to ADA specification No. 12.1999.

C-Testing

1-Transverse strength test: The resulted forty samples of auto polymerized acrylic resin (control and experimental specimens) that prepared for transverse strength test was collected and stored in distilled water for 48 hours at37±2°C. After conditioning period, the samples were tested by three points bending test by flexural testing machine. The test consisted of gradually applying a force to each specimen by using a universal test machine (Hydraulic press, LeyboldHarris Co., British)) at a crosshead speed of 5 mm/min until fracture occurred. The machine has three shafts in which the two inferiors serve to hold the sample and the superior one serves to apply force to the center of the sample. The three shafts have the same ray of 2.5 mm in order to avoid differences in the results. The center of the specimen was determined by using a millimeter ruler

and the resulting central point was marked with an OHP marker pen. The load was applied perpendicular to the center of the specimen. The fracture force was registered in Newton. All measurements were obtained on the same day. Transverse strength was calculated according to the following equation:

TS = 3WL/2bd2 Where

TS = transverse strength (MPa).

W=maximum load at midpoint of the sample (Kg).

L = distance between the supports (50 mm).

b = width of the sample (10mm).

d = thickness of the sample (2.5mm).

2- Impact strength test: The resulted forty samples of auto polymerized acrylic resin (control and experimental specimens) that prepared for impact strength test was collected and stored in distilled water for 48 hours at37±2°C. After conditioning period, the impact strength test was conducted following the procedure by the ISO 179 with impact testing device (Amity ville L.IN.Y New York USA). The specimen was supported horizontally and struck by free, swinging pendulum of 5 joules, the scale reading give the impact energy in joules. The charpy impacted strength of un-notched specimens was calculated in kilo joules per square meter. It is given by the formula:

Impact strength=A/YX103 Where

A=the impact energy in joules.

X=the width in millimeters of test specimen.

Y=the depth in millimeters of test specimen.

3-Statistical Analysis: Statistical analysis was performed with the SPSS software for Windows (v. 19.0) Mean, Standard deviation, Standard error , Minimum and Maximum were obtained for each group. The obtained data was tabulated and statistically analyzed using ANOVA (one way analysis of variance test) for assessing differences between more than two groups and LSD (least significant difference test) for assessing differences between two group means when ANOVA model was significant. Significance level equal to 0.05.

Result

Transvers Strength

The mean transvers strength values and standard deviations for each experimental group are presented in **Table 1**. A one way analysis of variance showed that the effect of different silver nitrate concentrations on transvers strength of cold cure acrylic was insignificant, $F(3,36) = 2.570$, $p = .069$, as shown in **Table 2.**

Table1: Mean transvers strength (MPa) values and std.deviation for experimental groups.

Cold cure acrylic	Mean	N	Std. Deviation	Std. Error of Mean	Minimum	Maximum
Control	64.2400	10	1.50200	.47497	62.10	66.30
9.375 PPm	64.9300	10	1.48926	.47094	62.20	67.10
15PPm	63.8300	10	2.12814	.67298	61.40	67.50
60PPm	62.8800	10	1.55621	.49212	61.20	66.20

Table 2: One way ANOVA for Transvers strength in relation to different Silver nitrate concentrations.

	Sum of Squares	df	Mean Square	F	Sig.
Between Groups	22.022	3	7.341	2.570	.069 *
Within Groups	102.822	36	2.856		
Total	124.844	39			

*P >0.05

Impact strength

The means and standard deviations for impact strength are displayed in Table 3. A one-way analysis of variance revealed significant differences between the groups F(3,36)= 51.445, p=.000. Table 4. Multiple comparisons using the LSD test revealed that control group is significantly lower than 15ppm (p=.000) and 60ppm groups (P=.000) but not 9.37PPM group (P=.349). Table 5.

Table3: Mean Impact strength (KJ/m²) values and std.deviation for experimental groups

Cold cure acrylic	Mean	N	Std. Deviation	Std. Error of Mean	Minimum	Maximum
Control	6.3450	10	.57417	.18157	5.62	7.25
9.375ppm	6.5730	10	.44164	.13966	5.75	7.23
15ppm	7.3860	10	.60511	.19135	6.50	8.31
60 ppm	9.0350	10	.51314	.16227	8.00	9.73

Table 4 **:** One way ANOVA for Impact strength in relation to different Silver nitrate concentrations

	Sum of Squares	df	Mean Square	F	Sig.
Between Groups	44.533	3	14.844	51.445	.000 *
Within Groups	10.388	36	.289		
Total	54.921	39			

P<0.05*

Table 5 Multiple comparison, LSD test

Cold cure acrylic	Cold cure acrylic	Mean Difference	Std. Error	Sig.
Control	9.375 ppm	-.22800	.24023	.349
	15 ppm	-1.04100*	.24023	.000 *
	60 ppm	-2.69000*	.24023	.000 *

* P<0.05

Discussion

Autopolymerizing acrylic resin is one of the most frequently used materials in dentistry. However, it has several disadvantages as poor mechanical properties. Attempts have been made to strengthen acrylic resin materials with either chemical modification with grafted co-polymers and stronger cross linkage or by the use of various reinforcing materials as inclusion of metals, glass, carbon, polyester and rigid polyethylene and zirconium oxide [17]. This study has attempt to modify autopolymerizing acrylic by incorporation of silver nitrate ,which has wide range of applications in many felids; medically such as relief of pain & fatigue , dropped into new born babies eyes at birth to reduce eyes infections and blindness [18], exhibit antimicrobial action against gram-positive and gram-negative bacteria and fungi [19,20], and has a less likely tendency than antibiotic to induce resistance due to its activity at multiple bacterial target sites[21], while in dentistry such as development of antimicrobial dental materials and equipment that can effectively prevent and\ or inhibit the growth of various microorganisms[22], detecting the permeability degradation and marginal integrity of dental composite restoration[23], and study its effect on transverse strength and impact strength.

Transverse strength; the force needed to deform the material to fracture or irreversible yield. It is a combination of compressive, tensile and shear strengths, all of which directly reflect the stiffness and resistance of a material to fracture [24]. The present study indicates that the transverse

strength of modified autopolymerizing acrylic was non-significantly influenced by the addition of silver nitrate with all concentrations, this might be due to Ag+ ions being reduced as the concentration of Ag increase, generating atom clusters and smaller particle size during the curing process which compete with complete polymerization process[25], the plasticization effect of the resultant residual monomer will reduce the molecular binding force between the reactant molecules allowing greater deformation upon stretching or flexion through exhibiting multiple micro fractures that weaken the AgNO3-loaded resin samples.

Impact strength; the ability of a material to resist a sudden high level force or shock. This study shows that the value of impact strength of modified autopolymerized acrylic was significantly improved by the addition of (15 and 60 ppm) concentrations of silver nitrate, while there was a non-significant improvement by the addition of (9.375 ppm) concentration of silver nitrate, this could be due to the formation of greater number of nucleation sites and smaller particle sizes, thereby generating more particles; the total particle-matrix interfacial surface area available for energy dissipation increase, so the critical stress for particle-matrix de-bonding also increase [19]. This improvement also could be due to the presence of the residual monomer; this plasticization effect render the fabricated acrylic resin samples more capable to absorb energy on impact and more resistant to fracture [2].

Conclusion

Within the limitations of this in vitro study the following conclusions can be drown:

1- Transverse strength of autopolymerizing acrylic was non-significantly influenced by the addition of silver nitrate with all concentrations.
2- Impact strength of autopolymerized acrylic was significantly improved by the addition of 15 and 60 ppm concentrations of silver nitrate, while there was a non-significant improvement by the addition of 9.375 ppm concentration of silver nitrate.
Further work is clearly needed to investigate the effect of addition of silver nitrate on other physical and mechanical properties of autopolymerizing acrylic.

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